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TECHNICAL BULLETIN

ULTRAVIOLET ERASING OF EPROM'S

The earliest electronic computers used a combination of semiconductor diodes and vacuum tubes to perform logic functions, and magnetic core circuits to perform memory functions. The initial transition to integrated circuits still left main frame computers in the form of magnetic core stacks—this was the last area within the computer to adopt solid state circuitry. The main reason was economic as core memory systems could be built at a cost less than that of other methods available at the time.

Rapid advances in Large Scale Integration (LSI) techniques and the decreasing cost of semiconductors in general reversed the conditions favoring core memory in the early 1970's. Increasing labor costs for the fabrication of core memory and the widespread proliferation and availability of low cost Metal-Oxide-Semiconductor (MOS) devices reinforced the trend in the mid 1970's towards semiconductors being the primary memory technology. Also, the inherent reliability of semiconductor memories led to their use in high performance applications in which core memory had proved unsatisfactory.

Now, the new memories are no longer limited to computers and have become a universal design element that is introducing the benefits of data storage to all electronics equipment industries.

WHAT IS A SEMICONDUCTOR MEMORY?

The basic configuration of a semiconductor memory consists of a matrix of "cells" where data is stored. Various types of memory storage have evolved—from simple diodes arranged in a matrix to gate and logic arrays, stored-charge devices and amorphous semiconductors.

Erasable memories use active transistor circuits as memory cells and are generally fabricated by MOS technology. MOS devices are classified according to different fabrication techniques, i.e. p-channel (P-MOS), n-channel (N-MOS) and complementary (C-MOS).

Two major classes of semiconductor memory have developed: Random Access Memory (RAM) and Read Only Memory (ROM). RAM is employed to store and retrieve digital data that is constantly changing in computer systems; ROM serves as a source of permanent data that is not lost when power is removed from the system.

Different system applications with their specific data storage applications have spawned the development of various categories of RAM and ROM memories, each with its own peculiar advantages and disadvantages. Only one of these will be addressed in this bulletin—the Ultraviolet-Erasable Programmable ROM, often abbreviated as EPROM or UV-PROM.

ROM generally signifies a mask-programmed ROM which obtains storage ability by virtue of the semiconductor manufacturing process. Data is permanently stored when the device is manufactured and cannot be altered. If an error was made in the mask (and the permanently programmed data), it almost invariably leads to the scrapping of the device. The procedure is also time-consuming and certainly not very well matched to today's rapidly changing technological advances. PROM's employ techniques that allow the complete device to be manufactured without programmed data and provide the user with access to input data. Data is inputted by a PROM programmer which accepts data either manually by keyboard or automatically from tape. Data is thus converted into the appropriate electrical format for the PROM being used. The nature of the PROM memory cells and the techniques required for programming vary with construction technology but always, unfortunately, once the bit patterns have been programmed into the memories they are permanent. The programmed PROM results in a device that is similar to a mask-programmed ROM — with the same disadvantages.

THE UV-ERASABLE PROM (EPROM)

The UV-erasable PROM has a fused silica lid positioned above the semiconductor chip, which permits ultraviolet radiation to penetrate the semiconductor. The EPROM is erased in this way rather than electrically as with RAM's, some ROM's and most recently with Electrically-Erasable-PROM's (EEPROM), also known as Electrically-Alterable-PROM's (EAPROM).

WHAT ADVANTAGES DO EPROM'S HAVE?

The attraction of the EPROM is its extreme usefulness in prototyping software codes in microprocessor designs. It typically takes several "passes" through a system before a program's code can be correct and optimized. Each "pass" requires a new program and a ROM that can be erased and reprogrammed quickly makes it much easier to optimize a program. For a complex project, UV-erasable PROM's can save months of trial-and-error programming.

An additional dimension of flexibility has been added to systems design because, even when the programmer is satisfied with the program, it can be changed at a later date to accommodate new systems features. Alternatively, the user can switch to mask-programmed ROM's or can program ROM's with identical pin assignments and power supply requirements.

In practice EPROM's are being increasingly designed as a permanent part of a system because of the severe price war that has resulted in prices that make them very competitive with the less flexible, non-erasable PROM's and ROM's. Lengthy turnaround times for custom-programmed circuits are avoided and they are now appearing in many unanticipated small volume production applications (even though they may never be programmed again), as well as for prototyping. Once the right program has been found, other UV-erasable PROM's may be programmed to duplicate the bit pattern of the prototype.

Ultimately, ROM's manufactured from specific masks to duplicate the bit pattern would be substituted for large production runs. In the latter case, the experimental EPROM would then be erased and moved to another experimental location.

HOW DO EPROM'S WORK?

The basic memory element was developed by Frohman-Bentchkowsky at Intel Corporation and was known as the Floating-Gate-Avalanche-Injection MOS (FAMOS) transistor. It was essentially a silicon gate MOS field effect transistor in which no connection was made to the gate. The gate was in fact electrically "floating" in an insulating layer of silicon dioxide. The devices have been fabricated in two structures: p-channel or n-channel. The p-channel devices were the first EPROM's available commercially, but many devices are now using n-channel technology. N-channel MOS devices have the advantage of being able to function with a single power supply.

By application of a sufficiently large potential difference between the source and drain, charge can be injected into the "floating" gate which induces a charge in the substrate. The source-to-drain impedance changes and a "p-channel" or "n-channel" is created, depending upon the type of substrate. The presence or absence of conduction is the principle of data storage. Application of short wave (254nm) ultraviolet light causes the gate charge to leak away and restores the device to its original unprogrammed state.

WHAT IS ULTRAVIOLET LIGHT?

Ultraviolet light is an invisible band of radiation beyond the violet end of the electromagnetic spectrum. It extends from a wavelength of 0.1 to about 380nm (nanometers), although the region between 180 and 380nm is the only part that is normally experienced because of the absorption of shorter wavelengths by air. The wavelength of specific interest in the UV-EPROM application is 253.7nm, which is usually rounded off to 254nm.

HOW MUCH ULTRAVIOLET LIGHT IS NEEDED FOR ERASURE?

The time required for complete erasure of the information on a cell is very consistent from device to device, provided that the fused silica window is clean and there are no pieces of dirt, grease or silicon fragments on the surface of the EPROM. In these cases the shadows reduce the amount of ultraviolet light falling on those cells obscured by the obstacle, thus increasing the time required for complete erasure. Awareness of the problems, and screening followed by careful cleaning of the fused silica window, can minimize the required erase times. For maximum irradiance at the chip, the tube or grid of the eraser should also be kept clean of grease and other ultraviolet-absorbing materials by periodically wiping it down with a solvent such as alcohol.

Most EPROM chip manufacturers have assigned **nominal erasing energies** to their devices to assist the user in determining the optimum erase time. Manufacturers usually specify an erasing energy of 15W-sec/cm², although many EPROM's require only 10 or even 6W-sec/cm² for complete erasure.

The manufacturer's recommended erasing time in seconds is obtained by multiplying the **nominal erasing energy** (W-sec/cm²) by 1,000,000 and dividing by the **ultraviolet irradiance** at the chip (in microwatts/cm²).

$$\text{Time (secs)} = \frac{\text{Nominal Erasing Energy (W-sec/cm}^2\text{) x 1,000,000}}{\text{Irradiance } (\mu\text{W/cm}^2)}$$

SIMULTANEOUS ERASING OF SEVERAL EPROM'S

The published erasure times given by some manufacturers of EPROM erasers are optimum times based on the ideal situation of one chip at the point of maximum irradiance. Because of the inadequate explanation of this fact, some confusion has arisen when simultaneously erasing several EPROM's, and incomplete erasure of one or more chips has occurred. The programmer has been uncertain as to whether the eraser was functioning incorrectly or that perhaps the chips were bad. There could be an alternative explanation and it is the purpose of this bulletin to explore the situation when erasing several EPROM's simultaneously.

The irradiance produced at the surface of the EPROM chip is dependent upon **where it is located with respect to the tube** of the eraser. For example, if it is located off to the side and near to the end of the tube it receives considerably less UV irradiance than a chip located directly below the center of the tube. Usually this latter location is that chosen by lamp manufacturers when specifying erasure times. However, these figures are usually meaningless if the eraser is loaded with more than one EPROM, because obviously only one chip can receive the maximum irradiance. The parameter is the time needed for erasing **all** of the EPROM's — including the worst placed EPROM (i.e. the chip receiving the least amount of 254nm energy per unit time).

The following table provides data concerning **estimated erasing times** for the least favorably situated chip in each of the 12 Spectroline® EPROM erasers:

ERASING TIME REQUIRED, IN MINUTES

	PE-140, PE-140T			PE-240T			PL-265T			PR-125T, PR-320T	PC-1100A, PC-2200A PC-3300A, PC-4400A	PC-4420A	PC-8820A
NOMINAL ERASING ENERGY	1 EPROM CHIP	3 EPROM CHIPS	9 EPROM CHIPS	2 EPROM CHIPS	4 EPROM CHIPS	12 EPROM CHIPS	2 EPROM CHIPS	5 EPROM CHIPS	30 EPROM CHIPS	1 CHIP TO FULL CAPACITY	1 CHIP TO FULL CAPACITY	1 CHIP TO FULL CAPACITY	1 CHIP TO FULL CAPACITY
6W-sec/cm²	12.5	13.8	15.3	10.4	10.9	13.6	10.4	10.9	13.6	5.9	5.4	4.0	2.5
10W-sec/cm²	20.8	22.9	25.6	17.4	18.1	22.7	17.4	18.1	22.7	9.8	9.0	6.7	4.2
15W-sec/cm²	31.2	34.5	38.4	26.0	27.2	34.1	26.0	27.2	34.1	14.7	13.5	10.0	6.3

IMPORTANT: The above erasing times are based upon typical peak irradiances of the erasers and are given only as estimates — **actual erasing times may vary**. The suggested operating procedure is to use the above table to select the estimated erasing time and then vary the exposure period until you determine the **minimum** amount of time required for complete erasure.

As with all metal vapor discharge lamps, the output of the ultraviolet tubes and grids in our EPROM erasers will gradually decrease throughout their life. Due to the general unpredictability of the rate of UV intensity decline, cumulative hour recorders in EPROM erasers cannot accurately indicate tube life. Use of a short wave UV radiometer is thus the most effective way of determining proper erasure time and monitoring the useful life of the ultraviolet light source. The Spectroline® DM-254X Meter is recommended for **measuring UV intensity**, while the DS-254E EPROMETER™ not only **measures UV intensity** but also **calculates the time needed for complete erasure**. Please contact the factory for complete information.

DOES THE EPROM WEAR OUT?

It has been noticed that repeated erasing and reprogramming of EPROM's appears to increase the required erasing time. Not much has been published regarding this phenomenon because EPROM's are usually not cycled that large a number of times—it can only be speculated that possibly some chemical changes take place within the device. The one thing that is certain is that it is dependent upon the erasing and programming techniques. Well over 100 programming and erase cycles still resulting in a usable EPROM have been reported in literature (1) using certain programming techniques and equipment, yet some reports have indicated only 30 to 50 times using other techniques.

Attempts have been made to "recondition" the devices by baking them prior to erasing—this technique has resulted in some reduction in the erase time. However, no method has gained widespread acceptance or recommendation because of its very limited need.

CAUTION

All Spectroline® EPROM erasing lamps and cabinets are provided with a safety interlock mechanism to protect against accidental exposure of eyes or skin to hazardous short wave ultraviolet light. Operation of the eraser is prevented unless the tray or drawer is fully and properly inserted into the housing. Any attempt to defeat the safety interlock may result in painful eye and/or skin burns or other harmful effects.

REFERENCE
(1) "How to Use 1702A MOS PROM's Reliably," Edwin Lee, Pro-Log Corporation, 2411 Garden Road, Monterey, California, August 1975.

NOTE: The data in this bulletin was compiled in September 1986 and subsequent changes in any of the Spectroline® EPROM erasers may affect the data.

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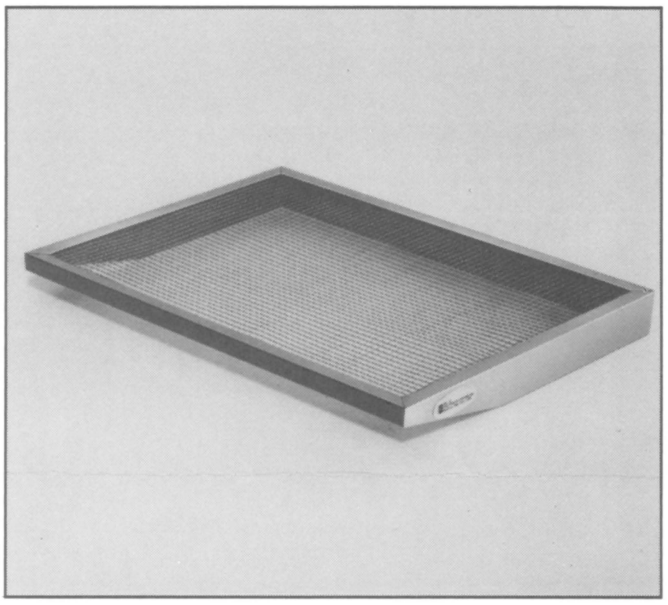
PRODUCT BULLETIN

SPECTROLINE® ELECTROSTATIC SHIELDS FOR PC-SERIES EPROM ERASING UV CABINETS

For reliable erasing of EPROMs mounted on printed circuit boards, or when the conductive foam pad is not used, Spectronics Corporation has developed the ES-Series electrostatic shields which serve to protect against potential electrostatic damage.



HIGH ELECTROSTATIC FIELD

The Spectroline® PC-Series EPROM erasing cabinets have an ultraviolet system which inherently generates a high electrostatic field (approximately 400 V/CM) in the space between the lamp and tray. Any device in this space will necessarily experience such a field. When silicon is exposed to ultraviolet, many "hot" carriers are generated which travel in basically random directions. With an electrostatic field, the carrier flow is diverted and electrons can become trapped in the gate oxide resulting in a V_{IH} shift.

DAMAGE TO EPROMS POSSIBLE

If all input leads are shorted together during erasure, no device field can exist and a V_{IH} shift will not occur. However, if the conductive foam pad is not used as recommended and the device is placed directly on the metal tray surface, enough non-planarity of the tray and/or misalignment of the pins normally exists that input pins may float electrically and be coupled up to the function breakdown voltage.

When EPROM devices are mounted on a PC board, it is often undesirable or impractical to remove them for erasure. In this case it is unrealistic to rely upon the conductive foam pad shorting all EPROM inputs together.

SHIELDS REDUCE ELECTROSTATIC FIELD

The Spectroline® ES-Series electrostatic shields are specially designed to reduce the electrostatic field within the cavity by a factor of approximately 15. This serves to protect EPROMs and other sensitive devices from electrostatic damage.

ORDERING INFORMATION

Model No.	For PC-Series Cabinet
ES-1100	PC-1100A
ES-2200	PC-2200A
ES-3300	PC-3300A
ES-4400	PC-4400A and PC-4420A
ES-8820	PC-8820A

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